2012

Combining outputs from the North American Regional Climate Change Assessment Program by using a Bayesian hierarchical model

Emily L. Kang
University of Cincinnati

Noel Cressie
University of Wollongong, ncressie@uow.edu.au

Stephan R. Sain
National Center For Atmospheric Research, Boulder, United States

Combining outputs from the North American Regional Climate Change Assessment Program by using a Bayesian hierarchical model

Abstract

We investigate the 20-year-average boreal winter temperatures generated by an ensemble of six regional climate models (RCMs) in phase I of the North American Regional Climate Change Assessment Program. We use the long-run average (20-year integration) to smooth out variability and to capture the climate properties from the RCM outputs. We find that, although the RCMs capture the large-scale climate variation from coast to coast and from south to north similarly, their outputs can differ substantially in some regions. We propose a Bayesian hierarchical model to synthesize information from the ensemble of RCMs, and we construct a consensus climate signal with each RCM contributing to the consensus according to its own variability parameter. The Bayesian methodology enables us to make posterior inference on all the unknowns, including the large-scale fixed effects and the small-scale random effects in the consensus climate signal and in each RCM. The joint distributions of the consensus climate and the outputs from the RCMs are also investigated through posterior means, posterior variances and posterior spatial quantiles. We use a spatial random-effects model in the Bayesian hierarchical model and, consequently, we can deal with the large data sets of fine resolution outputs from all the RCMs. Additionally, our model allows a flexible spatial covariance structure without assuming stationarity or isotropy.

Keywords

climate, change, assessment, program, regional, bayesian, combining, hierarchical, outputs, model, american, north

Disciplines

Physical Sciences and Mathematics

Publication Details

Kang, E. L., Cressie, N. & Sain, S. R. (2012). Combining outputs from the North American Regional Climate Change Assessment Program by using a Bayesian hierarchical model. Journal of the Royal Statistical Society. Series C: Applied Statistics, 61 (2), 291-313.

Journal of the Royal Statistical Society. Series C: Applied Statistics

Volume 61, Issue 2, March 2012, Pages 291-313

Combining outputs from the North American Regional Climate Change Assessment Program by using a Bayesian hierarchical model

Kang, E.L.[a] , Cressie, N.[b], Sain, S.R.[c]

[a] University of Cincinnati, United States

[b] Ohio State University, Columbus, United States

[c] National Center for Atmospheric Research, Boulder, United States

Abstract

We investigate the 20-year-average boreal winter temperatures generated by an ensemble of six regional climate models (RCMs) in phase I of the North American Regional Climate Change Assessment Program. We use the long-run average (20-year integration) to smooth out variability and to capture the climate properties from the RCM outputs. We find that, although the RCMs capture the large-scale climate variation from coast to coast and from south to north similarly, their outputs can differ substantially in some regions. We propose a Bayesian hierarchical model to synthesize information from the ensemble of RCMs, and we construct a consensus climate signal with each RCM contributing to the consensus according to its own variability parameter. The Bayesian methodology enables us to make posterior inference on all the unknowns, including the large-scale fixed effects and the small-scale random effects in the consensus climate signal and in each RCM. The joint distributions of the consensus climate and the outputs from the

RCMs are also investigated through posterior means, posterior variances and posterior spatial quantiles. We use a spatial random-effects model in the Bayesian hierarchical model and, consequently, we can deal with the large data sets of fine resolution outputs from all the RCMs. Additionally, our model allows a flexible spatial covariance structure without assuming stationarity or isotropy. © 2011 Royal Statistical Society.

Author keywords

Downscaling; North American Regional Climate Change Assessment Program; Posterior distribution; Regional climate model; Spatial random-effects model

ISSN: 00359254 **Source Type:** Journal **Original language:** English
DOI: 10.1111/j.1467-9876.2011.01010.x **Document Type:** Article

References (44)

View in table layout

Page Export Print E-mail Create bibliography

Baladandayuthapani, V., Mallick, B.K., Young Hong, M., Lupton, J.R., Turner, N.D., Carroll, R.J.

1 **Bayesian hierarchical spatially correlated functional data analysis with application to colon carcinogenesis**

(2008) *Biometrics*, 64 (1), pp. 64-73. Cited 25 times.
doi: 10.1111/j.1541-0420.2007.00846.x

FIND@UOW

Banerjee, S., Carlin, B., Gelfand, A.E.

2 (2004) *Hierarchical Modeling and Analysis for Spatial Data*. Cited 551 times.
Boca Raton: Chapman and Hall

FIND@UOW

Banerjee, S., Gelfand, A.E., Finley, A.O., Sang, H.

3 **Gaussian predictive process models for large spatial data sets**

(2008) *Journal of the Royal Statistical Society. Series B: Statistical Methodology*, 70 (4), pp.

825-848. Cited 71 times.
doi: 10.1111/j.1467-9868.2008.00663.x

FIND@UOW

Berliner, V.M., Kim, Y.

4 **Bayesian design and analysis for superensemble-based climate forecasting**

(2008) *Journal of Climate*, 21 (9), pp. 1891-1910. Cited 13 times.
http://ams.allenpress.com/archive/1520-0442/21/9/pdf/i1520-0442-21-9-1891.pdf
doi: 10.1175/2007JCLI1619.1

FIND@UOW

Berliner, L.M., Wikle, C.K., Cressie, N.

5 **Long-lead prediction of Pacific SSTs via Bayesian dynamic modeling**

(2000) *Journal of Climate*, 13 (22), pp. 3953-3968. Cited 64 times.

FIND@UOW

Buser, C.M., Künsch, H.R., Weber, A.

6 **Biases and Uncertainty in Climate Projections**

(2010) *Scandinavian Journal of Statistics*, 37 (2), pp. 179-199. Cited 4 times.
doi: 10.1111/j.1467-9469.2009.00686.x

FIND@UOW

Christensen, W.F., Sain, S.R.

7 **Latent Variable Modeling for Integrating Output from Multiple Climate Models**

(2012) *Mathematical Geosciences*, 44 (4), pp. 395-410.
doi: 10.1007/s11004-011-9321-1

FIND@UOW

Cressie, N., Johannesson, G.

8 **Spatial prediction of massive datasets**

(2006) *Proc. Australian Academy of Science Elizabeth and Frederick White Conf.*, pp. 1-11. Cited 5 times.

Canberra: Australian Academy of Science.

FIND@UOW

Cressie, N., Johannesson, G.

9 **Fixed rank kriging for very large spatial data sets**

(2008) *Journal of the Royal Statistical Society. Series B: Statistical Methodology*, 70 (1), pp. 209-226. Cited 64 times.

doi: 10.1111/j.1467-9868.2007.00633.x

FIND@UOW

Cressie, N., Kang, E.

10 **High-resolution digital soil mapping: Kriging for very large datasets**

(2010) *Proximal Soil Sensing*, pp. 49-63. Cited 7 times.

(eds R. Viscarra-Rossel, A. B. McBratney and B. Minasny). Dordrecht: Springer.

FIND@UOW

DuMouchel, W.

11 **Bayesian meta-analysis**

(1990) *Statistical Methods for Pharmacology*, pp. 509-529. Cited 59 times.

(ed. D. A. Berry). New York: Dekker.

FIND@UOW

Fennessy, M.J., Shukla, J.

12 **Seasonal prediction over North America with a regional model nested in a global model**

(2000) *Journal of Climate*, 13 (14), pp. 2605-2627. Cited 43 times.

FIND@UOW

Furrer, R., Sain, S.R., Nychka, D., Meehl, G.A.

13 **Multivariate Bayesian analysis of atmosphere-ocean general circulation models**

(2007) *Environmental and Ecological Statistics*, 14 (3), pp. 249-266. Cited 37 times.

doi: 10.1007/s10651-007-0018-z

Gilks, W., Richardson, S., Spiegelhalter, D.

14 (1996) *Markov Chain Monte Carlo in Practice*. Cited 3197 times.
(eds). London: Chapman and Hall.

Kanamitsu, M., Ebisuzaki, W., Woollen, J., Yang, S.-K., Hnilo, J.J., Fiorino, M., Potter, G.L.

15 **NCEP-DOE AMIP-II reanalysis (R-2)**

(2002) *Bulletin of the American Meteorological Society*, 83 (11), pp. 1631-1643+1559. Cited 1338 times.

Kang, E.L., Cressie, N.

16 **Bayesian inference for the spatial random effects model**

(2011) *Journal of the American Statistical Association*, 106 (495), pp. 972-983. Cited 3 times.
http://pubs.amstat.org/doi/pdf/10.1198/jasa.2011.tm09680
doi: 10.1198/jasa.2011.tm09680

Kang, E.L., Noel, C., Tao, S.

17 **Using temporal variability to improve spatial mapping with application to satellite data**

(2010) *Canadian Journal of Statistics*, 38 (2), pp. 271-289. Cited 7 times.
http://www3.interscience.wiley.com/cgi-bin/fulltext/123461074/PDFSTART
doi: 10.1002/cjs.10063

Kaufman, C.G., Sainy, S.R.

18 **Bayesian functional ANOVA modeling using Gaussian process prior distributions**

(2010) *Bayesian Analysis*, 5 (1), pp. 123-150. Cited 14 times.
http://ba.stat.cmu.edu/journal/2010/vol05/issue01/kaufman.pdf
doi: 10.1214/10-BA505

Lahiri, S.N., Kaiser, M.S., Cressie, N., Hsu, N.-J.

19 **Prediction of Spatial Cumulative Distribution Functions Using Subsampling**

(1999) *Journal of the American Statistical Association*, 94 (445), pp. 86-97. Cited 44 times.

FIND@UOW

Lopes, H.F., Salazar, E., Gamerman, D.

20 **Spatial dynamic factor analysis**

(2008) *Bayesian Analysis*, 3 (4), pp. 759-792. Cited 19 times.
http://ba.stat.cmu.edu/journal/2008/vol03/issue04/lopes.pdf
doi: 10.1214/08-BA329

FIND@UOW

Massam, H.

21 **Prior distributions for covariance/precision matrices, part 1**

(2009) *Int. Soc. Baysn Anal. Bull.*, 16, pp. 8-11. Cited 2 times.

FIND@UOW

Massam, H.

22 **Prior distributions for covariance/precision matrices, part 2**

(2010) *Int. Soc. Baysn Anal. Bull.*, 17, pp. 5-7.

FIND@UOW

McAvaney, B., Covey, C., Joussaume, S., Kattsov, V., Kitoh, A., Ogana, W., Pitman,
23 A., (...), Zhao, Z.

Model evaluation

(2001) *Climate Change 2001: the Scientific Basis*, pp. 471-524. Cited 122 times.
(ed. J. T. Houghton). Cambridge: Cambridge University Press.

FIND@UOW

Mearns, L., Arritt, R., Biner, S., Bukovsky, M., McGinnis, S., Sain, S., Caya, D., (...), Snyder, M.

24

The North American Regional Climate Change Assessment program: overview of Phase I results

(2010) *Bull. Am. Meteorol. Soc*
Submitted to

FIND@UOW

☐ **A regional climate change assessment program for North America**

25 (2009) *Eos*, 90 (36), p. 311. Cited 56 times.
doi: 10.1029/2009EO360002

FIND@UOW

☐ Meehl, G., Boer, G., Covey, C., Latif, M., Stouffer, R.

26 **The coupled model intercomparison project (CMIP)**

(2000) *Bull. Am. Meteorol. Soc.*, 81, pp. 313-318. Cited 160 times.

FIND@UOW

☐ Reilly, J., Stone, P.H., Forest, C.E., Webster, M.D., Jacoby, H.D., Prinn, R.G.

27 **Climate change: Uncertainty and climate change assessments**

(2001) *Science*, 293 (5529), pp. 430+431+433. Cited 70 times.

FIND@UOW

☐ Sain, S.R., Furrer, R.

28 **Combining climate model output via model correlations**

(2010) *Stochastic Environmental Research and Risk Assessment*, 24 (6), pp. 821-829. Cited 7 times.
doi: 10.1007/s00477-010-0380-5

FIND@UOW

☐ Sain, S., Furrer, R., Cressie, N.

29 **Combining ensembles of regional climate model output via a multivariate Markov random field model**

(2011) *Ann. Appl. Statist.*, 5, pp. 150-175.

Sain, S.R., Nychka, D., Mearns, L.

30 **Functional ANOVA and regional climate experiments: A statistical analysis of dynamic downscaling**

(2011) *Environmetrics*, 22 (6), pp. 700-711. Cited 3 times.

doi: 10.1002/env.1068

Schliep, E.M., Cooley, D., Sain, S.R., Hoeting, J.A.

31 **A comparison study of extreme precipitation from six different regional climate models via spatial hierarchical modeling**

(2010) *Extremes*, 13 (2), pp. 219-239. Cited 5 times.

doi: 10.1007/s10687-009-0098-2

Schneider, S.H.

32 **What is 'dangerous' climate change?**

(2001) *Nature*, 411 (6833), pp. 17-19. Cited 136 times.

doi: 10.1038/35075167

Shi, T., Cressie, N.

33 **Global statistical analysis of MISR aerosol data: A massive data product from NASA's Terra satellite**

(2007) *Environmetrics*, 18 (7), pp. 665-680. Cited 11 times.

doi: 10.1002/env.864

Smith, R.L., Tebaldi, C., Nychka, D., Mearns, L.O.

34 **Bayesian modeling of uncertainty in ensembles of climate models**

(2009) *Journal of the American Statistical Association*, 104 (485), pp. 97-116. Cited 42 times.

doi: 10.1198/jasa.2009.0007

FIND@UOW

35 Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., Tignor, M., (...), Miller, H. (2007) *Climate Change 2007: the Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC* (eds). Cambridge: Cambridge University Press.

FIND@UOW

36 Tebaldi, C., Sansó, B.

Joint projections of temperature and precipitation change from multiple climate models: A hierarchical Bayesian approach

(2009) *Journal of the Royal Statistical Society. Series A: Statistics in Society*, 172 (1), pp. 83-106. Cited 29 times.

doi: 10.1111/j.1467-985X.2008.00545.x

FIND@UOW

37 Tebaldi, C., Smith, R.L., Nychka, D., Mearns, L.O.

Quantifying uncertainty in projections of regional climate change: A Bayesian approach to the analysis of multimodel ensembles

(2005) *Journal of Climate*, 18 (10), pp. 1524-1540. Cited 178 times.

doi: 10.1175/JCLI3363.1

FIND@UOW

38 Webster, M.

Communicating climate change uncertainty to policy-makers and the public: An Editorial Comment

(2003) *Climatic Change*, 61 (1-2), pp. 1-8. Cited 24 times.

doi: 10.1023/A:1026351131038

FIND@UOW

Wigley, T.M.L., Raper, S.C.B.

39 **Interpretation of high projections for global-mean warming**

(2001) *Science*, 293 (5529), pp. 451-454. Cited 254 times.

doi: 10.1126/science.1061604

FIND@UOW

Wikle, C.K., Cressie, N.

40 **A dimension-reduced approach to space-time Kalman filtering**

(1999) *Biometrika*, 86 (4), pp. 815-829. Cited 130 times.

FIND@UOW

Xue, Y., Vasic, R., Janjic, Z., Mesinger, F., Mitchell, K.E.

41 **Assessment of dynamic downscaling of the Continental U.S. Regional Climate using the Eta/SSiB regional climate model**

(2007) *Journal of Climate*, 20 (16), pp. 4172-4193. Cited 22 times.

doi: 10.1175/JCLI4239.1

FIND@UOW

Yang, R., Berger, J.

42 **Estimation of a covariance matrix using the reference prior**

(1994) *Ann. Statist.*, 22, pp. 1195-1211. Cited 95 times.

FIND@UOW

Zhang, J., Craigmile, P.F., Cressie, N.

43 **Loss function approaches to predict a spatial quantile and its exceedance region**

(2008) *Technometrics*, 50 (2), pp. 216-227. Cited 3 times.

doi: 10.1198/004017008000000226

FIND@UOW

Zhao, Y., Staudenmayer, J., Coull, B.A., Wand, M.P.

44 **General design Bayesian generalized linear mixed models**

(2006) *Statistical Science*, 21 (1), pp. 35-51. Cited 45 times.

doi: 10.1214/088342306000000015

Kang, E.L.; University of Cincinnati, 839 Old Chemistry Building, PO Box 0025, Cincinnati, OH 45221-0025, United States; email:kangel@ucmail.uc.edu

1 of 1

Top of page

About Scopus
What is Scopus
Content coverage
What do users think
Latest
Tutorials
Developers

Contact and Support
Contact and support
Live Chat

About Elsevier
About Elsevier
About SciVerse
About SciVal
Terms and Conditions
Privacy Policy